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VENOUS PULSE.

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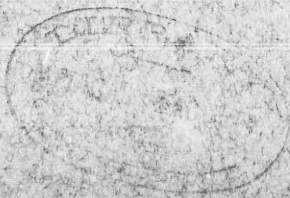
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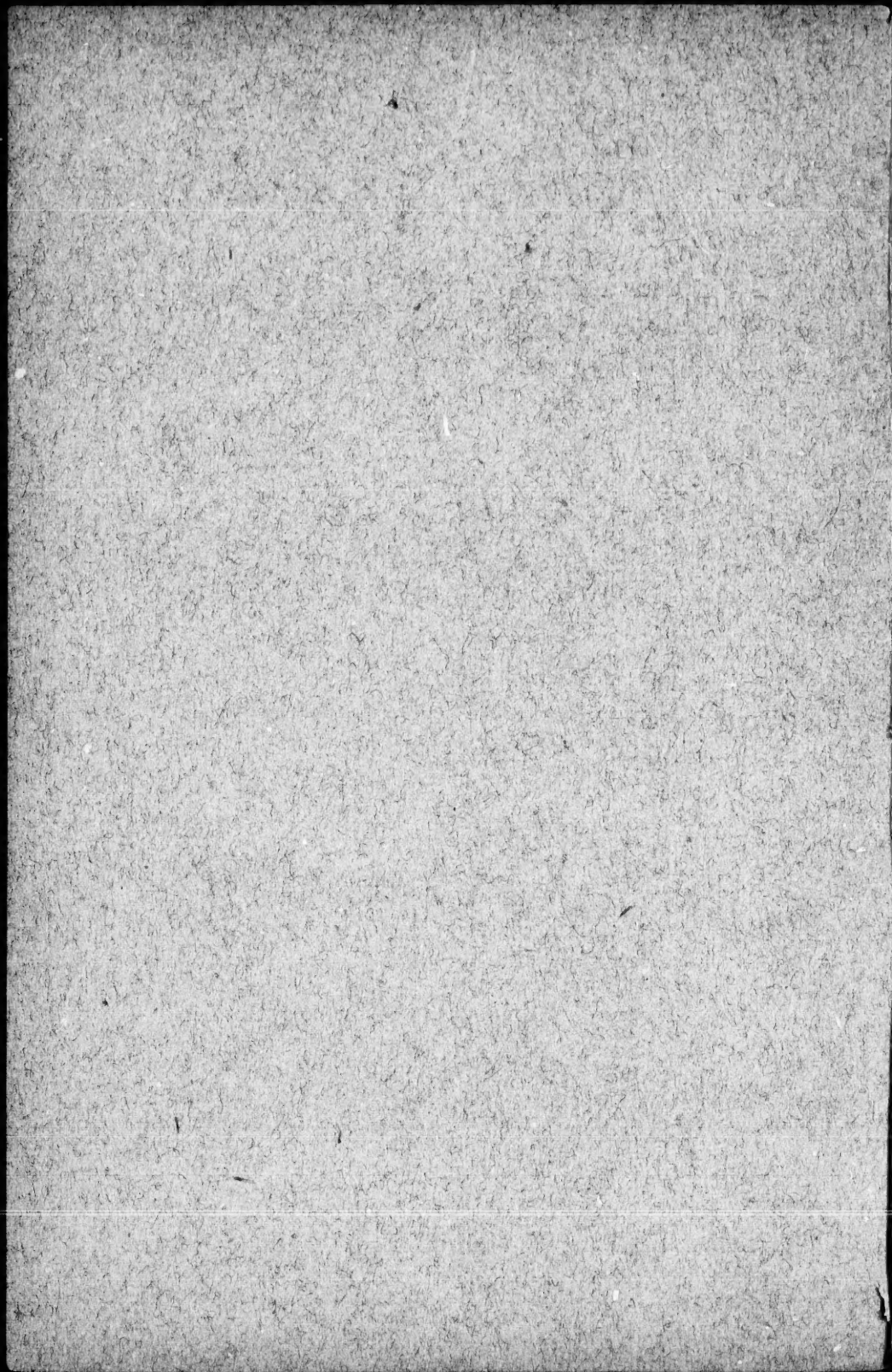
(From the Physiological Institute of the University of Breslau.)

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## THE RATE OF PROPAGATION OF THE VENOUS PULSE.<sup>1</sup>

By DR. W. S. MORROW,

Lecturer in Physiology, McGill University.

*(From the Physiological Institute of the University of Breslau.)*

This research was undertaken at the suggestion of Prof. Karl Hürthle, of Breslau, to determine the rate at which the venous pulse travels. Before I began my experiments Prof. Hürthle had satisfied himself that a venous pulse could frequently be observed in the veins of the neck and extremities of normal dogs.

He had also devised very sensitive apparatus for recording the same (Hürthle's venous manometers). Tracings of the pulse in the veins of the extremities of normal dogs, taken with this apparatus, are shown in Figures 1 and 2. Other investigators had also observed the venous pulse in the extremities of normal animals, and still others (2 and 3) had studied it in normal and pathological human subjects, but no one had undertaken to measure the rate at which it travelled. It seemed probable that this would be found different from that of the arterial pulse, on

<sup>1</sup> This research was reported in German in Pflüger's Archives for March.

account of the differences in pressure in the two kinds of vessels.

My experiments were all performed on dogs, which first received an injection of morphine, and were then thoroughly anaesthetized with a mixture of equal parts of chloroform and ether.

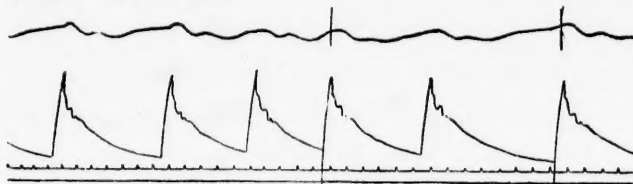


FIG. 1.—Pressure tracing from artery (below) and femoral vein (above).  
Time  $\frac{1}{5}$  seconds. From a dog.

Pulse tracings were taken on a blackened surface simultaneously from two points on the veins. At the same time a chronograph was arranged to mark seconds or fifths of seconds on the recording surface, so as to indicate the rate at which it was moving. By this means it was possible to estimate the time elapsing between the appearance of a certain wave on the tracing taken from a vein at a point near the heart, and on that taken farther away from the heart. Then, in order to estimate the rate at which a given pulse wave travelled, it was only necessary to know, in addition, the distance of the points on the veins from one another measured along the line of blood flow, or more exactly the difference in the distances of the two points from the heart (right auricle).

The recording surface employed was that of Hürthle's large clockwork kymograph.

The pulse waves were recorded by inserting a fine glass canula, with a long drawn out point, into the vein through a side branch. (See Fig. 3.) The canula was then connected by rubber tubing with one of Hürthle's venous manometers, which marked the waves on the surface of the kymograph.

Hürthle's venous manometers which were used in the experiments consist of small metallic tambours, 10 mm. in diameter, covered over with thin rubber tissue slightly stretched. On the centre of this membrane rests a light metal disc of 8 mm. diameter, which supports, and transmits its movements to a lever moving very easily and writing at one end on the kymograph with a suitably shaped quill. The lever magnifies the up and down movements of the disk as 120:5.

On account of the very slight variations in pressure underlying the venous pulse, friction has to be minimized as much as possible. This is accomplished by adjusting the lever against the kymograph by a screw arrangement, so that it exerts the slightest possible pressure upon it. The manometers, the glass canulas, and the rubber tubing connecting them were filled with saturated solution of magnesium sulphate, which prevented the clotting of the blood in the vein over the opening of the canula.

It was possible, by measuring the distance that the lever of the manometer was raised, and comparing this with the effects of known pressures of water at the close of the experiments, to estimate approximately the pressure present in the veins at any point represented on the tracings.

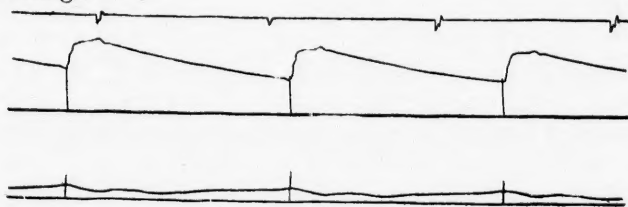


FIG. 2. — Pressure tracing from artery (above) and brachial vein (below).  
Time in seconds. From a dog.

The rate of propagation was measured in two regions:

1. Through the external jugular vein.
2. Through the inferior vena cava to the femoral vein.

In the first case, pulse tracings were taken simultane-



ously from the central and peripheral ends of the external jugular, by inserting one canula into it through the posterior scapular vein, and another through the external maxillary.

To measure the rate of propagation through the inferior vena cava, one tracing was taken as above from the central end of the external jugular, and the other from the femoral

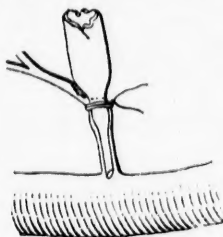


Fig. 3.

vein by introducing a canula into it through the deep femoral. At the end of the experiments the distances of the points on the veins used from the right auricle were measured; if one indicates the distance of the point nearest the heart by  $e_1$ , and the distance of the point farthest away by  $e_n$ , then the length of vein for which the rate of propagation of the pulse waves is estimated is  $e_n - e_1$ .

Finally, at the end of the experiment the points on the two tracings, corresponding to one another in time, were established by causing both levers to write vertical lines, with the kymograph standing still. The marking of these points was sometimes attended with considerable difficulty, on account of the waves being less sharp than those of the arterial pulse.

In most cases, however, a fair number of satisfactory markings could be made. An example of these markings is seen in Fig. 4. The distance apart of the vertical lines indicates how much later the wave began in the distal part of the vein than in the central, the exact time being estimated by comparison with the horizontal line between the tracings, on which seconds are marked.

If now one indicates with ( $a$ ) the distance in centimetres between the vertical lines marking the beginning of a given wave in the two tracings, with ( $s$ ) the rate at which the recording surface travels in centimeters, with ( $e_u - e_l$ ) the length of vein being studied, and with ( $v$ ) the rate of propagation of the pulse in that length of vein, then

$$v = s \frac{(e_u - e_l)}{a}$$

As regards the presence of a pulse in the veins of the animals experimented on, it may be said that one could always be observed and recorded in the central end of the jugular. In most cases it could also be recorded from the distal end of the jugular and from the femoral; but the waves were sometimes not sharp enough for satisfactory marking. The estimations reported below were taken

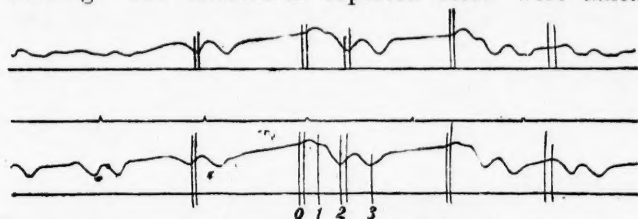


FIG. 4.—Pressure tracing from central (below) and peripheral end (above) of external jugular vein. Time in seconds. From a dog.

from cases where the markings were considered reliable enough to make the errors very slight. It is a noteworthy fact, that the best tracings were frequently obtained from the smallest and weakest dogs. Similar observations have been made by Gottwald (1) on dogs, and Gerhardt (2) on human subjects. Gerhardt claims to have observed the venous pulse most frequently in weak and anæmic girls.

Although a discussion of the form of the venous pulse does not properly find a place in this paper, it is necessary to allude to it briefly in order to have names for the various waves whose rate of propagation was studied. Following Fredericq (4), Gerhardt (2) and others, I distinguish, as may be seen in Fig. 4, a presystolic wave, 0, a systolic

wave, 1, a first and second diastolic wave, 2 and 3. Such a typical and complete form, however, cannot always be observed, but one or more of the above mentioned waves is often absent from the tracing.

#### THE RATE OF PROPAGATION THROUGH THE JUGULAR VEIN.

The results of the measurements made in the different experiments were arranged in tabular form, as given below, and also the rate of propagation and the pressure in the jugular, estimated by the methods described above. The results are set down in order according to the velocity.

TABLE I.  
Rate of Propagation of the Presystolic Wave.  
(All measurements in centimeters.)

Difference in the distance from the right auricle of the distal and proximal points on the veins. $e_u - e_i$	Distance on recording surface between beginning of wave in the two tracings. $a$	Distance travelled by recording surface per second. $s$	Calculated velocity of pulse. $v$	Pressure in central end of jugular in centimeters water. $p$
$23.5 - 12.5 = 11$	.065	1.85	313	5.5
	.060	1.70	312	5.5
	.070	1.80	283	5.4
	.080	1.75	241	3.2
	.100	1.83	201	3.5
Average			270	4.6

In the remaining tables only the calculated results will be given, namely, the rate of propagation in centimeters per second and the pressure in centimeters of water in the central end of the jugular vein.

TABLE II.  
Presystolic Wave.

$v$	$p$
228	8.5
225	9.5
218	8.8
194	8.5
173	8.5
170	9.0
Average 201	8.8

TABLE III.  
Presystolic Wave during Dyspnea.

$v$	$p$
257	8.9
254	9.1
235	9.3
235	9.4
231	9.2
221	8.5
208	9.3
205	9.2
Average 220	9.1



TABLE IV.  
Systolic Wave.

<i>v</i>		<i>p</i>
364	....	5.5
337	....	4.9
330	....	5.2
291	....	5.8
264	....	5.5
259	....	4.7
248	....	4.2
248	....	3.9
248	....	3.5
228	....	6.0
194	....	4.5
Average 268		4.9

TABLE VI.

First Diastolic Wave.

<i>v</i>		<i>p</i>
278	....	2.9
264	....	2.7
257	....	2.8
254	....	2.9
252	....	2.7
248	....	2.5
248	....	2.5
241	....	3.0
220	....	3.2
214	....	2.8
205	....	2.4
198	....	3.7
198	....	2.7
198	....	2.0
196	....	2.7
193	....	2.0
180	....	2.0
165	....	2.0
Average 223		2.6

TABLE V.  
Systolic Wave.

<i>v</i>		<i>p</i>
161	..	7.5
147	....	7.7
143	....	6.8
134	....	7.6
130	....	7.3
115	....	6.9
Average 138		7.3

TABLE VII.

First Diastolic Wave.

<i>v</i>		<i>p</i>
139	....	6.8
130	....	6.3
117	....	6.3
117	....	5.5
116	....	6.0
114	....	6.1
108	....	6.1
103	....	6.0
102	....	5.3
100	....	4.9
99	....	5.3
98	....	5.7
98	....	5.2
95	....	5.5
93	....	5.5
92	....	5.5
92	....	5.5
89	....	4.8
86	....	5.0
85	....	5.2
85	....	5.0
Average 103		5.6

RATE OF PROPOGATION OF THE PULSE THROUGH THE  
INFERIOR VENA CAVA.TABLE VIII.  
Presystolic Wave.

<i>v</i>		<i>p</i>
138	....	2.4
128	....	3.1
128	....	3.1
122	....	2.7
106	....	2.0
92	....	2.7
89	....	2.7
Average 115		2.7

TABLE IX.  
First Diastolic Wave.

<i>v</i>		<i>p</i>
117	....	2.0
113	....	2.2
104	....	2.6
104	....	1.5
93	....	2.0
92	....	2.6
Average 104		2.1

TABLE X.

First Diastolic Wave.

<i>v</i>	<i>p</i>
136	6.5
127	6.5
120	6.5
119	6.5
112	6.3
101	7.1
140	4.6
136	4.2
130	4.8
124	4.8
114	4.5
112	3.2
110	2.9
106	2.8
101	2.9
101	2.5
Average 118	4.8

Dyspnoea.

TABLE XI.

Second Diastolic Wave during  
Dyspnoea.

<i>v</i>	<i>p</i>
70	-2.5
69	-2.6
67	-2.3
65	-2.5
64	-2.0
63	-2.0
Average 66	-2.3

In the following table the average rates and pressures from the preceding tables are brought together:

TABLE XII.

Table.	Average velocity.	Average pressure.	Wave.
I. ....	270	4.6	Presystolic
II. ....	201	8.8	"
III. ....	230	9.1	"
IV. ....	268	4.9	Systolic
V. ....	138	7.3	"
VI. ....	223	2.6	I. Diastolic
VII. ....	103	5.6	"
VIII. ....	115	2.7	Presystolic
IX. ....	104	2.1	I. Diastolic
X. ....	118	4.8	"
XI. ....	66	-2.3	II. Diastolic

Jugular vein.

Through inferior vena  
cava to femoral.

The results of the investigation may be summarized as follows:

1. The changes in the pressure of blood within the right auricle and great veins are propagated through the larger veins of the trunk and extremities, causing a venous pulse.
2. The rate of propagation of this venous pulse varies between one and three meters per second in round numbers. This is much slower than the rate of propagation of the arterial pulse, which is to be explained by the lower pressure within the veins, and the differences in the walls of the two kinds of vessels.

3. A direct proportion between rate of propagation and pressure within the external jugular vein could not be demonstrated.

4. Some of the waves, especially the presystolic and the systolic, travel faster than others.

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- (3) Friedreich, Deutsches Arch. f. klin. Med., Vol. 1, p. 241.
- (4) Frédéricq, Travaux du lab. de Léon Frédéricq, Vol. 3, p. 85